THE WEATHER AND CIRCULATION OF MARCH 1959

Record Cold in Alaska But Mild Temperatures in the Remainder of the United States

CARLOS R. DUNN

Extended Forecast Section, U.S. Weather Bureau, Washington, D.C.

1. INTRODUCTION

The departures from normal of circulation and temperature for March 1959 were rather small over most of the contiguous United States. Westerly flow, similar to the normal [6], prevailed in the mid-troposphere, and maritime polar air masses, with their moderating, springtime effects, dominated the weather. However, the precipitation was more abnormal. There were periodically heavy rain and snow falls as vigorous Lows developed in the Southwest and moved across eastern United States. Some regions received 200–300 percent of their normal precipitation.

In sharp contrast to the mild weather in the contiguous States was the bitter cold throughout the State of Alaska. Long-period Alaskan records were broken, and the reported mean temperatures were more typical of midwinter than early spring. For example, the monthly mean temperature at Barrow was a frigid 27° F. below zero.

Meanwhile, the Hawaiian Islands had unusually warm, dry weather. Honolulu, for example, reported a record high mean temperature and little precipitation. There were just 6 days with measurable rainfall, and the total for the month was only 7 percent of normal.

2. THIRTY-DAY MEAN CIRCULATION

The monthly mean circulation at 700 mb. for March 1959 consisted of a large-amplitude, three-wave pattern in high latitudes and a smaller-amplitude, four-wave pattern in middle latitudes (fig. 1). These two wave trains were approximately 180° out of phase. Only the trough in Eurasia extended continuously across all latitudes, and even it had a marked slope from northeast to southwest. Associated with these truncated, out-of-phase troughs and ridges were several confluence zones with accompanying strong winds. The most prominent ones were in the Atlantic and eastern Pacific, where the height anomalies (fig. 1) indicate stronger-than-normal westerly geostrophic winds. In fact, wind speed maxima were located in both of these regions, and mean speeds were more than 8 m.p.s. above normal (fig. 2). The center in the Atlantic was a primary wind maximum, but the one in the eastern Pacific was essentially just an eastward extension of a larger primary wind maximum located in mid-ocean. All of these wind speed maxima were well east of their normal positions (indicated by arrowheads on heavy dashed lines in fig. 2).

In Eurasia the mean winds were generally weak. Residual blocking over Europe, which was associated with a split jet stream, produced a large area of subnormal wind over central Europe but supernormal wind to the north and south. One jet stream axis was depressed and flowed across northern Africa; the other was displaced north of the normal position, producing wind speeds up to 9 m.p.s. above normal between Scandinavia and Spitzbergen. There were no organized jet streams at the 700-mb. level over Asia.

Returning to the 30-day mean circulation over the oceans (fig. 1), we note that the troughs as well as the primary wind maxima were displaced eastward from their normal positions. This eastward shift of the Asiatic coastal trough resulted in above normal heights and abnormally anticyclonic conditions over Japan and eastern Siberia. The cyclonic areas were also displaced eastward, producing significant negative anomalies in the central Pacific Ocean and Alaska.

The largest anomalies were in northern latitudes, where the 700-mb. heights were far enough above normal to result in a High over Kamchatka, the approximate location of the normal Low, and also far enough below normal to produce a trough over Alaska, near the position of the normal ridge. This anomalous situation affected the downstream pattern, so that the trough normally found over eastern Canada was displaced approximately 25° of longitude eastward to southern Greenland, reducing heights in that area to 510 feet below normal, the largest anomaly in the Northern Hemisphere.

In retrospect, it appears that the block over Europe and the unusually strong trough in western Siberia, through the flux of vorticity, molded the well-marked wave train downstream. In addition, the eastward displacement of waves was favored by stronger-than-normal polar westerlies.

In the United States 700-mb. height departures from normal were small (fig. 1). Over the western States positive anomalies were associated with the flat ridge along the coast. In the eastern States there were weak negative anomalies over a broad band, typical of a flat mean trough. The latter feature suggests that cyclonic activity during March was uniformly distributed over the eastern two-thirds of the United States.

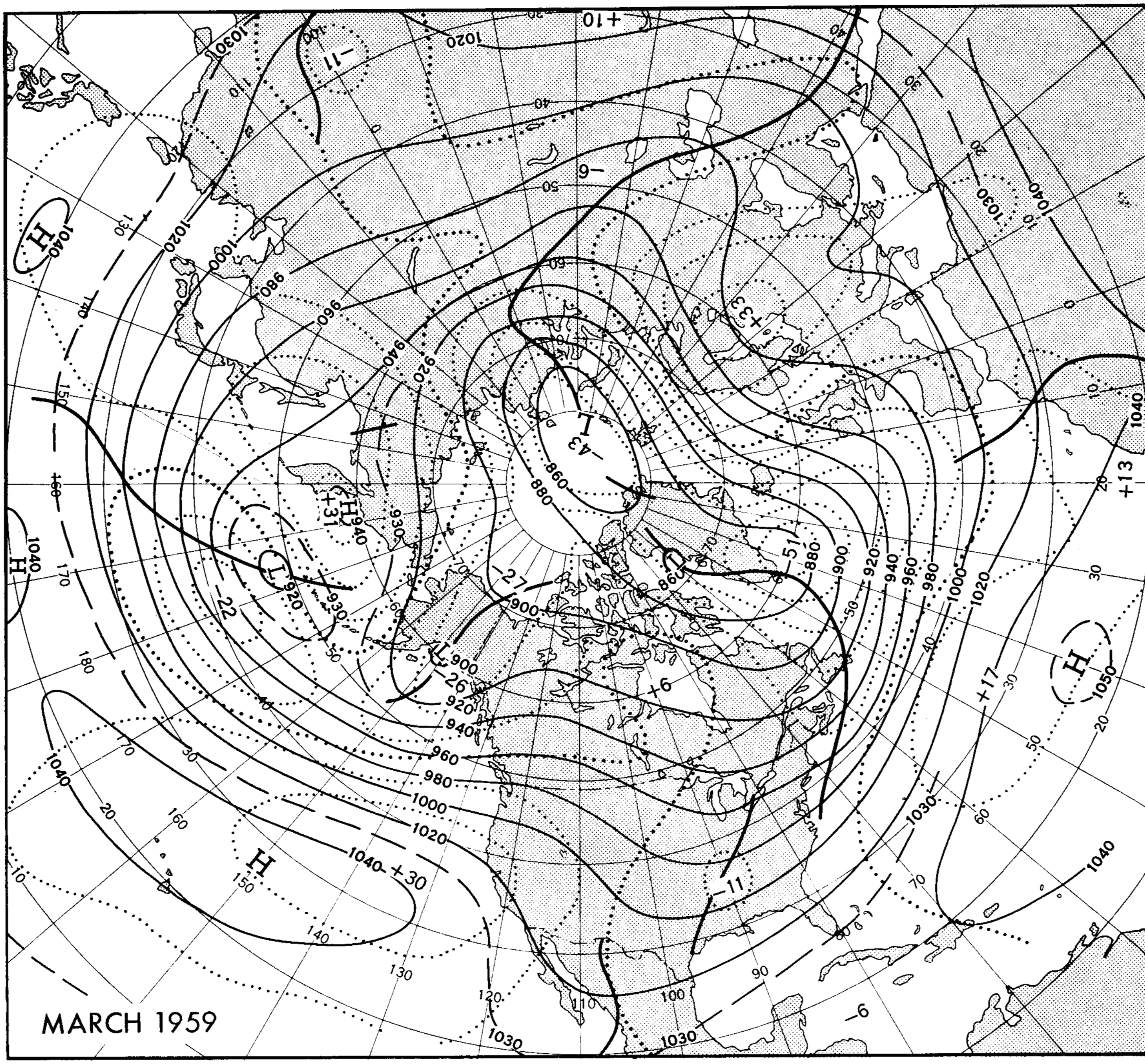

FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for March 1959. Mean ridge in the western and trough in the eastern United States were associated with stormy weather east of the western massif. Abnormally deep trough brought cold weather to Alaska.

3. CHANGE IN MEAN CIRCULATION FROM FEBRUARY TO MARCH

The pronounced block, which was located over western Europe during February [2], was much weaker and farther east during March. This modification of the circulation produced over Great Britain the largest month-to-month height change in the Northern Hemisphere (−610 ft.) and effected over Russia lesser height rises (fig. 3). This was associated with dry weather over Russia and much storminess over Great Britain.

In other areas of the Northern Hemisphere the height changes (fig. 3) were similar to the 700-mb. height departures from normal, which were referred to previously (fig. 1). Hence, in these areas the circulation anomalies for March can be looked upon largely as anomalous height changes from February to March. The rises over eastern Siberia and the eastern Pacific, and the falls over Alaska and central Pacific, all had their counterparts in the height anomaly field. To some extent the same was true in eastern North America, where heights rose in Canada and fell over the United States, resulting in weaker-than-normal west winds or height gradient from the southeastern United States to Hudson Bay.

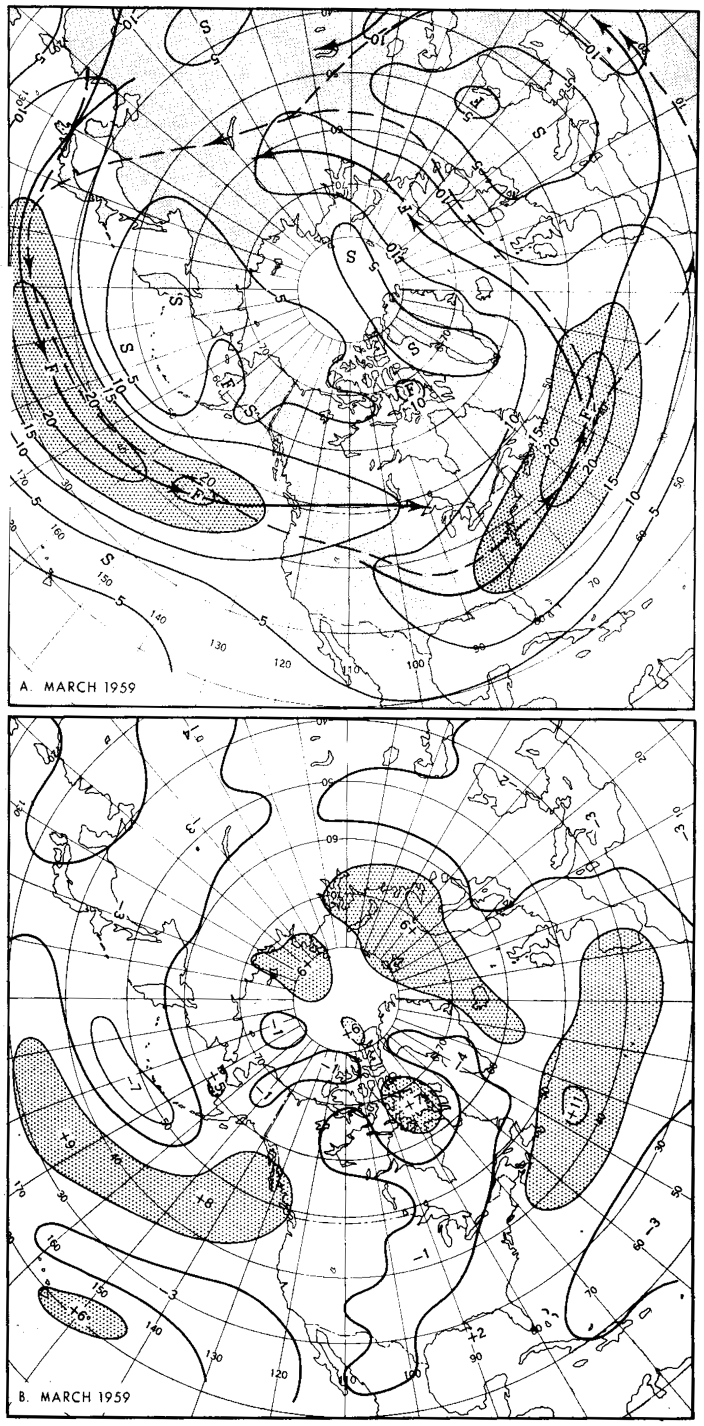

FIGURE 2.—(A) Mean 700-mb. isotachs and (B) departures from monthly normal wind speeds, both in meters per second, for March 1959. Solid arrows in (A) indicate principal axes of maximum winds, and dashed arrows their normal March positions. Regions with wind speeds greater than 15 m.p.s. and anomalies greater than 5 m.p.s. are stippled. Principal wind maxima were located over the oceans east of their normal positions.

4. RECURRENT CIRCULATION AND WEATHER

The 5-day mean flow patterns during March resembled each other and were quite similar to the 30-day mean flow. This is illustrated by the geographical frequencies of

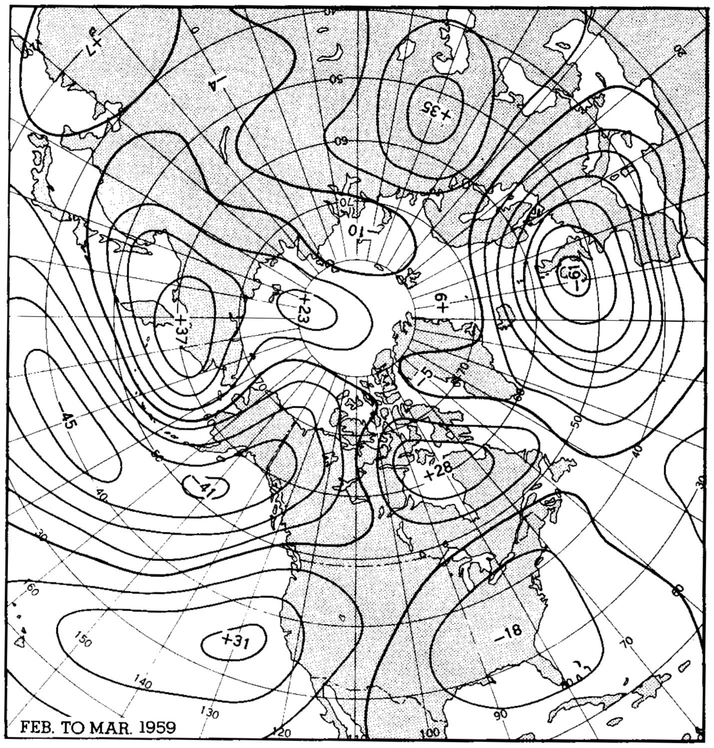

FIGURE 3.—Difference between monthly mean 700-mb. height anomaly for February and March 1959 (March minus February) in tens of feet. Largest falls were over Great Britain. Changes in many areas have striking resemblance to 700-mb. height anomalies for March (fig. 1).

700-mb. 5-day mean troughs and ridges (fig. 4) and by their relationship to the 30-day mean chart (fig. 1). The bands of high frequency of troughs and ridges were narrow, indicating a small variation in the longitudinal position of the troughs and ridges. One exception is the eastern United States, where the 5-day mean troughs were rather uniformly distributed from the Mississippi Valley to the Atlantic Coast.

It is particularly noteworthy that the positions of the 5-day mean troughs and ridges clustered around their respective 30-day mean troughs and ridges. This means that the 30-day mean accurately portrayed the predominant circulation regime of March and was not merely the average of several heterogeneous, short-lived circulations.

The 30-day mean flow of small amplitude across North America was accompanied by zonal trajectories of the Highs for March (Chart IX in [4]). The continental polar anticyclones, which formed in western Canada, glanced east-southeastward and remained almost entirely in Canada. They affected only the northeastern United States where the monthly mean thickness (fig. 5) and surface temperatures (fig. 7) averaged below normal. The remainder of the United States was dominated by maritime Pacific air masses, which also moved eastward across the country. A few anticyclonic centers had trajectories from the Pacific through the Northwest, but many of the Highs first appeared over the Plains and Central States and subsequently moved eastward into the Atlantic Ocean.

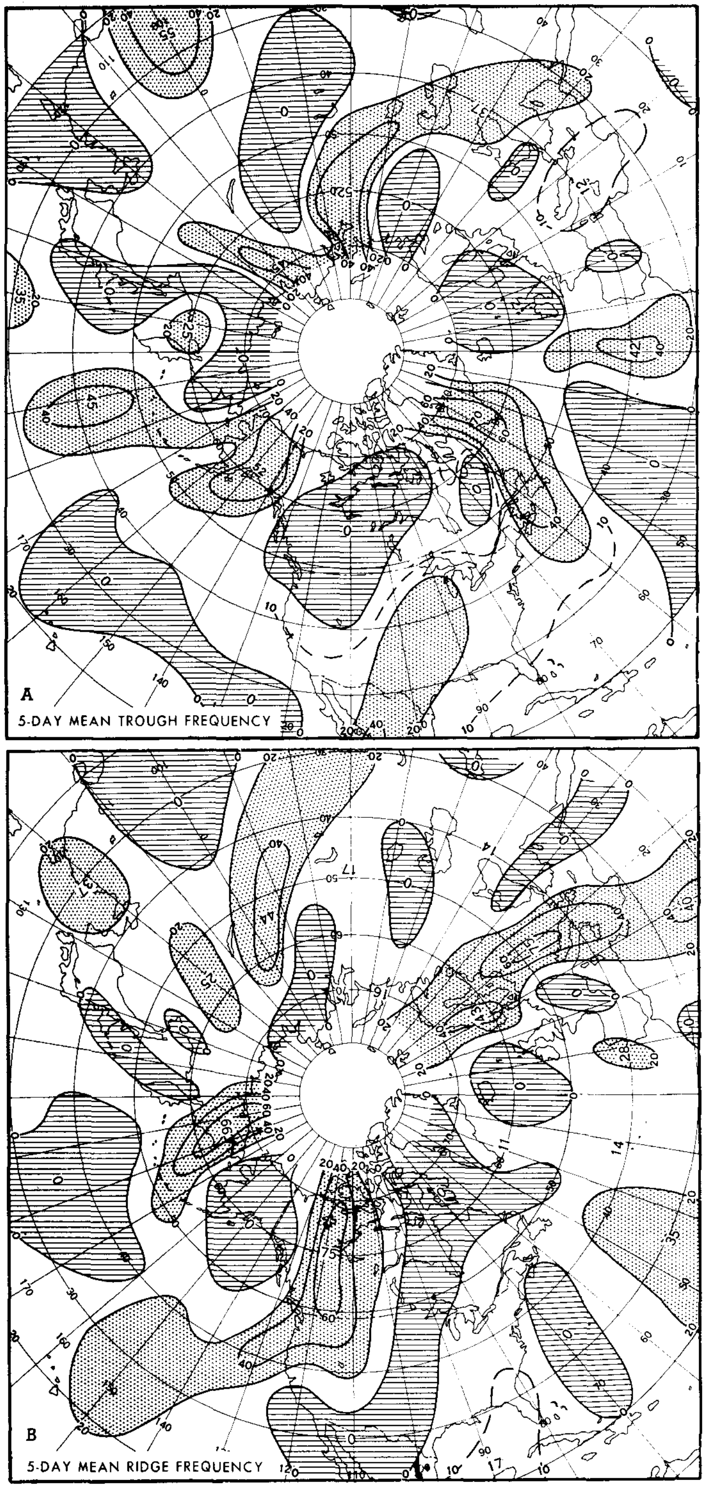

FIGURE 4.—Percent of the time that (A) troughs and (B) ridges on 5-day mean 700-mb. charts were located within 10° longitude intervals at latitudes from 20° N. to 70° N. for March 1959. The data were adjusted to an equivalent basis with 10° at 50° N. as the unit. Isoline interval is 20 percent. Areas with frequency greater than 20 percent are stippled; zero areas are hatched. Note high frequency of troughs and ridges near the locations of the 30-day mean troughs and ridges, respectively (fig. 1).

These maritime air masses had a thickness or mean temperature of the layer from 700 to 1000 mb. that was above

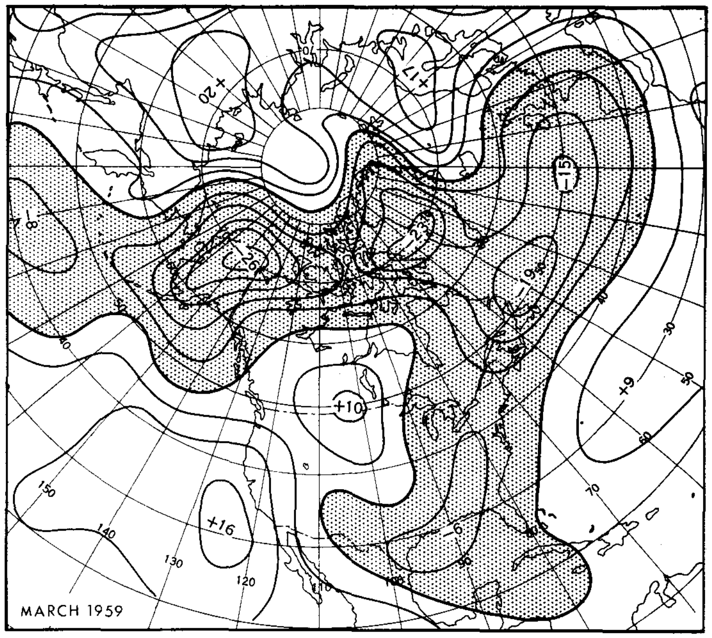

FIGURE 5.—Departure from monthly normal of the mean thickness (700–1000 mb.) for March 1959 in tens of feet. Isoline interval is 50 feet. Below normal values are stippled. Pattern over the United States bears a striking resemblance to the surface temperature anomalies (fig. 7). Extreme negative departures over Alaska were associated with record cold weather.

normal for the northern areas of the United States. This was particularly true for Montana and the Dakotas, where in March continental polar air masses are required to produce subnormal thickness. However, the same maritime Pacific air masses produced below normal thickness in the southern States (fig. 5).

The same was generally true for the accompanying surface temperatures (fig. 7), but this month an exception existed in the Far Northwest where subnormal surface temperatures were associated with above normal 30-day mean thicknesses. The coolest weather here occurred during the second and fourth weeks [7], when there was a strong flow of abnormally cold air from the Arctic and Alaska (fig. 5) into the Northwest. These air masses had a short and rapid trajectory over the ocean, thus minimizing the diabatic heating, so that the air was still cool when it reached the northwestern United States. During the fourth week the cooling was further enhanced by cyclonic flow aloft.

Along the California coast the weather was unusually warm. Both San Francisco and San Diego, which have long periods of record, reported new high mean temperatures for March. Furthermore, temperatures averaged above normal every day of the month at San Diego and were below normal only one day out of the month at San Francisco. Previously, several authors [1, 3] of this series of articles have related the persistently above normal temperatures in recent years along the California coast to abnormalities of the circulation and of sea-surface temperature. This March the record high temperatures

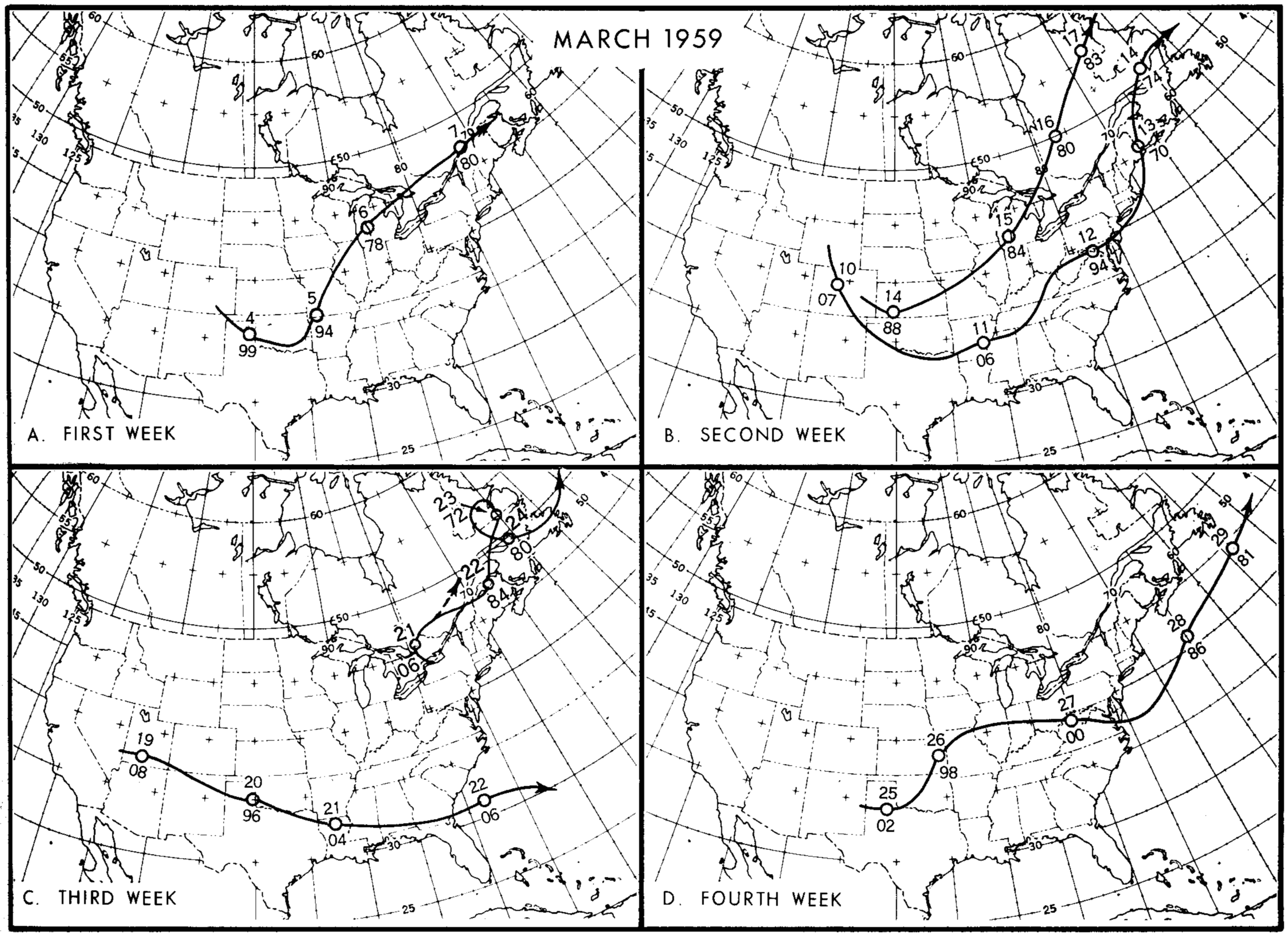

FIGURE 6.—Tracks of selected major cyclones which produced intense storms over the United States during March. Circles are the 1200 GMT locations of cyclone on date indicated by number above position. Number below is central pressure of Low in tens and units of millibars. Each week at least one severe storm moved out of the Southwest producing heavy snow and rain over large areas east of the Continental Divide.

follow directly from the above normal heights at 700 mb., and in addition, from the greater than normal northeasterly flow at 700 mb. and sea level, producing foehn winds for the area south of San Francisco (fig. 1, and Chart XI in [4]).

The cyclones, with two exceptions, which had tracks over the United States also had origins there (Chart X in [4]). Several Lows formed in the Atlantic Seaboard States, but the storms which originated in the Southwest contributed most to the weather over the United States. Each week at least one major cyclone formed over the southern Rocky Mountain States and produced severe weather along its eastward track through the central and eastern United States. A detailed descripition of the effects of these storms is given in [7].

During the first week of March a major storm marked by heavy rains, damaging winds, blowing dust, and drifting snow moved from Colorado northeastward across the Great Lakes into Canada (fig. 6A). The weather during the second week was influenced mainly by two disturbances which reached strong storm intensity as they moved northeastward (fig. 6B). The first storm, 11th to 13th, moved erratically from the lower Mississippi Valley to a position just off the north Atlantic coast and finally turned northward across eastern Maine. This storm produced heavy rains in the South and heavy snows in the Northeast, as high winds raked the entire east coast. More heavy rains in the South and a band of heavy drifting snow from Nebraska to Michigan resulted from the second storm of that week (14th to 16th) which moved from the lower Great Plains across the Great Lakes. During the third week the incidence of Southwest storms continued, but the cyclone which formed over Utah on the 19th moved in an east-southeasterly direction with its path traversing the Gulf Coast States (fig. 6C). In addition, a cyclone formed over Lake Ontario and slowly traced an erratic track across the Maritime Provinces of Canada (fig. 6C), creating stormy conditions in New England on March 21. The mild, sunny weather east of the Rocky Mountains during the first part of the fourth week of March was

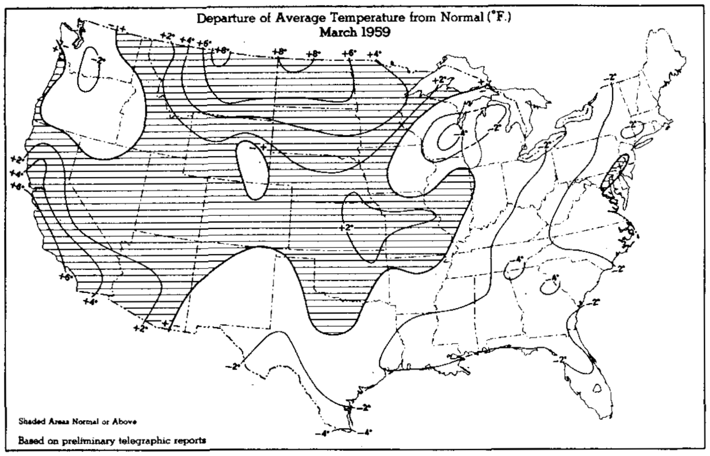

FIGURE 7.—Departure of average surface temperature from normal (° F.) for March 1959. Largest anomalies were in the northern Plains and Rocky Mountain States, but the positive anomalies along the California coast were associated with record temperatures (from [7]).

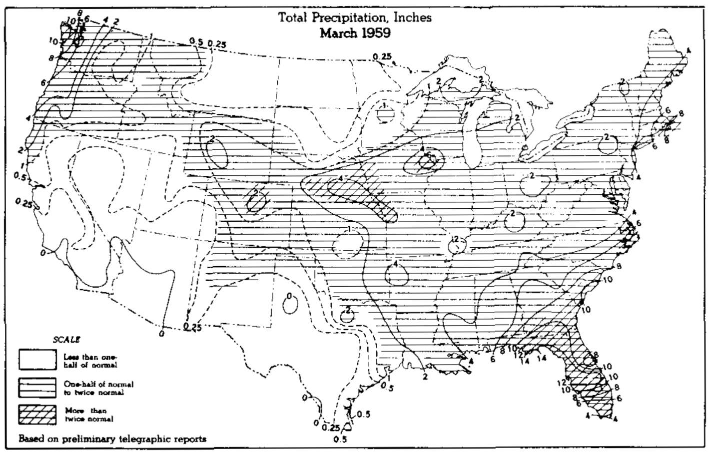

FIGURE 8.—Total precipitation (inches) for March 1959. Record amounts fell in Florida (from [7]).

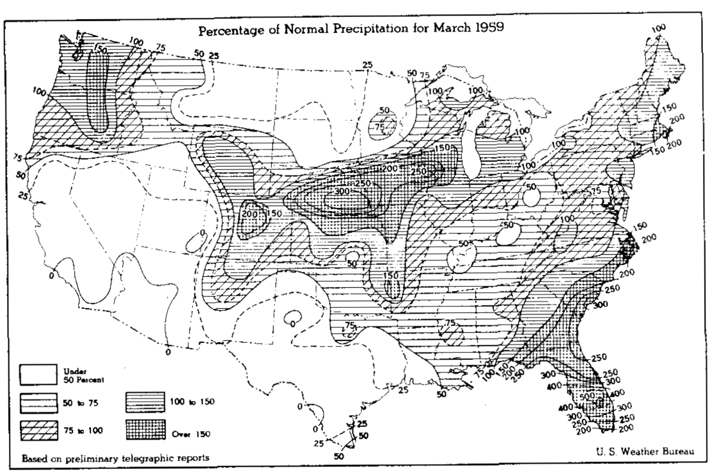

FIGURE 9.—Percentage of normal precipitation for March 1959. March was abnormally wet in the southeastern, northeastern, central, and northwestern States but unusually dry in the northern Plains, northern Rocky Mountains, and the Southwest (from [7]).

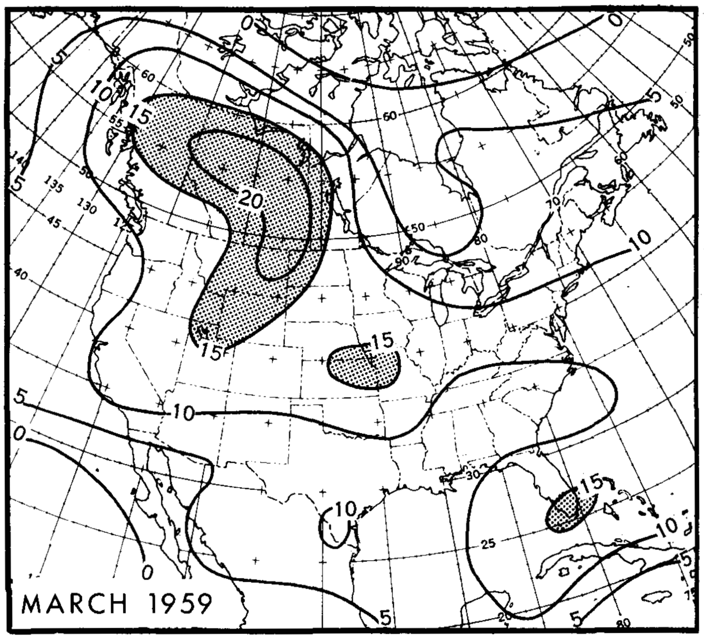

FIGURE 10.—Number of days in March 1959 with fronts of any type within unit squares (with sides approximately 500 miles). All frontal positions are taken from *Daily Weather Map*, 1:00 p.m. EST. Areas with 15 or more days with fronts are stippled. Active fronts were frequently located in Florida, Central Plains, and the Northwest.

interrupted by stormy weather as still another Texas disturbance moved northeastward on the 25th to 27th from the Southwest across New Jersey (fig. 6D).

The severity of the weather associated with these "Southwest Lows" is attested by the summary of the monthly weather at Dubuque, Iowa, which felt the full brunt of several of these storms. It was reported that the precipitation for March was the heaviest since the beginning of records in 1851. The snowstorm of the 4th and 5th brought the greatest amount of snow ever recorded in one 24-hour period for any month. The 6.50 inches of moisture for the month exceeds by 1.48 inches the previous wettest March recorded in 1852. The total monthly snowfall of 30.2 inches is the greatest for any March and the greatest for any month of the year since January 1929. Similar reports of record-breaking weather came from stations in Nebraska and Wisconsin.

The bulk of the precipitation over the United States during March (figs. 8, 9) was produced by the major storms whose tracks are shown in figure 6. However, additional rainfall did occur in the Southeast, associated with fronts which were prevalent over Florida and the Gulf of Mexico (fig. 10). Some of the precipitation was cold-frontal in nature, but the majority was produced by incipient cyclone waves and over-running of the cold air by tropical air masses. Tampa reported the wettest March on record; other Florida stations broke various precipitation records.

In the Northwest above normal precipitation occurred with faster-than-normal west-southwesterly flow across the mountain ranges (fig. 1), which intensified orographic lifting. Also favorable were the frequent invasions of maritime Pacific fronts (fig. 10) and cyclonic flow aloft. (See *Daily Weather Map* [5].)

That precipitation which fell east of the Rocky Mountains occurred under cyclonically curved 700-mb. mean flow and weak easterly anomalous flow in the Kansas-Missouri-Illinois area; both types of flow have been related empirically to vertical motion and precipitation. However, the explanation for the precipitation which occurred in the easterly flow north of the daily Lows, along the eastern slopes of the Rocky Mountains in Colorado and Wyoming, is not easily extracted from the monthly mean circulation at the 700-mb. level. The vertical motion and precipitation in these central Rocky Mountain States were enhanced by orographic effects not reflected in the upper-level circulation. Also, the precipitation occurred during a few short periods which were not typical of the predominant pattern of the region and consequently would not be reflected in the 30-day mean circulation.

5. RELATION OF PRECIPITATION TO VERTICAL MOTION

Of course, subjective evaluation of the monthly mean flow in terms of the average vertical motion or precipitation is rather crude, but until recently, it has not been practical to objectively estimate the vertical motion. Now, the availability of operational baroclinic models and electronic computers enables us to compute, objectively, the vertical motion for a midtropospheric level. The National Meteorological Center of the U.S. Weather Bureau at Suitland, Md., using a two-level baroclinic model, estimates twice daily the concurrent vertical motion at 600 mb. from initial (observed) data.

The 30-day mean of these values for March 1959 (fig. 11) is a logical pattern roughly consistent with the concomitant mean 700-mb. circulation. In general in figure 11, descending motion (negative values) is found west of the troughs in the northwesterly flow and ascending motion (positive values) east of the troughs in the southerly flow. Exceptions are the negative values just off the northeastern coast of the United States, under and east of the mean trough (fig. 1, 11). This, at least at first thought, does not fit the accepted relationship between horizontal circulation pattern and associated vertical motion, but further inspection of figure 1 reveals that subnormal 700-mb. heights and marked anomalous, northerly flow extended from eastern Canada to New England, suggesting that cold subsiding air masses frequently invaded the area in question, off the northeastern coast of the United States.

Portions of the 30-day mean vertical motion were correlated with the total monthly precipitation (fig. 8). The descending motion over the extreme Southwest and the northern Plains States was related to the driest areas this March. Prescott, Ariz., which had no precipitation, and

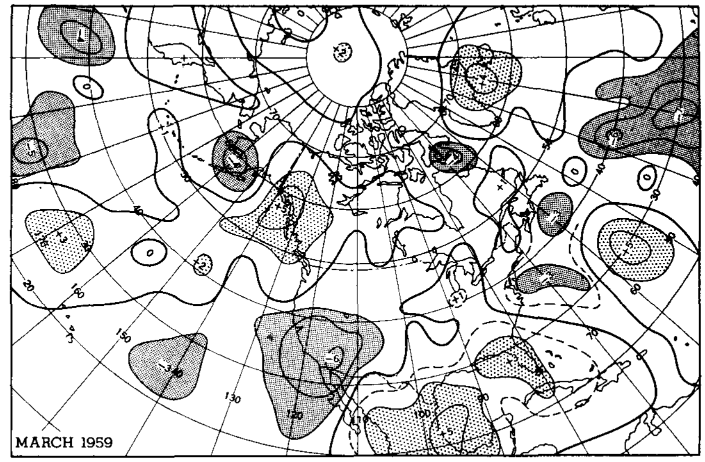

FIGURE 11.—30-day mean vertical motion at the 600-mb. level in millimeters per second for March 1959. Map was obtained by averaging the 60 available twice-daily values computed from baroclinic model and observed data. Isoline interval is 2 millimeters per second. Absolute values greater than 2 are stippled. Descending motion (negative) and ascending motion (positive) tend to be located east of the 30-day ridges and troughs, respectively.

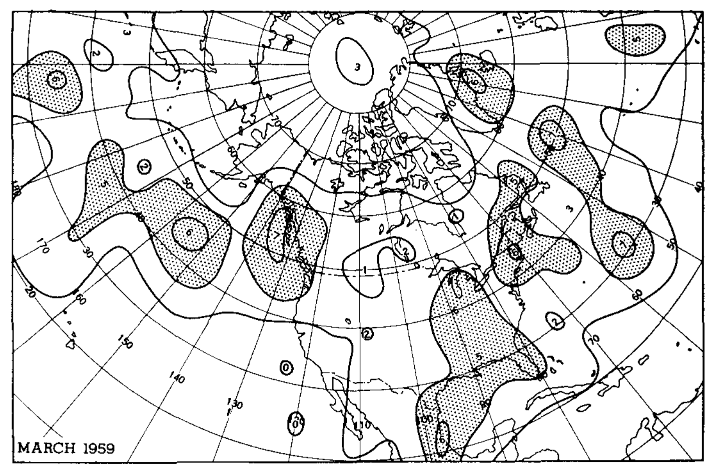

FIGURE 12.—30-day mean of only the ascending (positive) daily vertical motion for March referred to in legend of figure 11. Isoline interval is 2 millimeters per second. Values greater than 4 are stippled. Pattern resembles the total monthly precipitation (fig. 8).

Los Angeles, Calif., reported record dryness for March. Helena, Mont., had the driest March since 1881. The ascending motion over the Far Northwest and the States bordering the Gulf of Mexico fit the precipitation pattern quite well. However, pronounced discrepancies existed in the Nebraska-Kansas-Iowa and Northeast areas where sizable amounts of precipitation occurred in regions of little or no mean ascending motion. This could result from the averaging process where large ascending motions during short periods of storminess would be counteracted by long periods of subsidence. Therefore, the mean of only the positive values (ascending motion) was obtained (fig. 12). As expected, there was considerable ascending motion in these wet regions. Apparently, west of the mean troughs, on the western fringe of the precipitation areas, there were periods of both ascending and descending motion associated with the lifting and precipitation north and east of the daily storms and the subsidence in the cool air behind these same storms as they moved eastward. The availability of moisture, which is an additional requirement for precipitation, has not been considered in this brief investigation, and should be included in any further study.

6. ALASKAN COLD AND HAWAIIAN WARMTH

Most of Alaska experienced a record-breaking cold March (table 1). Barrow, Fairbanks, and Nome, well distributed stations with long periods of record, had the coldest March on record and Anchorage the second coldest. Departures from normal of the monthly mean temperatures were as large as two or three standard deviations, a rather rare event. Fairbanks, with 16° F. below normal, had the most extreme anomaly, but Barrow, with a frigid mean temperature of 27° F. below zero, suffered the coldest weather in the absolute sense. At the latter city the maximum daily temperature did not exceed −5° F., and the minimum was always colder than −21° F.

This cold over Alaska was produced by stronger than normal flow between the mean ridge over eastern Siberia and the trough over Alaska (fig. 1), which continually advected cold air masses from the Arctic Basin into Alaska. This was a very persistent pattern, as illustrated by the 5-day mean trough and ridge frequencies (fig. 4) and produced over Alaska the coldest mean thickness anomaly for the Northern Hemisphere (fig. 5).

While the Alaskans were shivering in record-breaking cold weather, the Hawaiians basked in record-smashing warmth (table 1). At Honolulu, the daily maxima averaged 79° F. and the minima 71° F. for the month of March. Of more significance was the monthly mean temperature of 74.7° F., the absolute highest since records began in 1905. This month's mean temperature represents a departure of +2.5° F., which is large for this subtropical station that has a standard deviation of only 1.0° F. Similar weather was experienced at Lihue, Kauai, where a record monthly mean temperature of 74.3° F. produced an anomaly of +3.7° F., almost 3 standard deviations above normal.

This warmth was associated with a deficit of precipitation at both stations. Honolulu reported only 0.17 inch, 2.13 inches below normal, and Lihue had 1.37 inches, 2.70 inches less than normal.

TABLE 1.—*Alaskan and Hawaiian surface temperatures (° F.) for March 1959*

Station	Monthly mean	Normal	Anomaly	Standard deviation	Year records start
Alaska					
Anchorage	14.0	24.8	−10.8	4.6	1916
Barrow	*−26.6	−14.9	−11.7	4.0	1921
Fairbanks	*−6.6	9.0	−15.6	6.0	1906
Juneau	33.8	32.8	+1.0	2.8	1915
Nome	*−5.3	8.5	−13.8	6.8	1907
Hawaiian Islands					
Honolulu	*74.7	72.2	+2.5	1.0	1905
Lihue	*74.3	70.6	+3.7	1.3	1905

*Record for March.

The dry and extremely warm weather occurred with a stronger than normal subtropical ridge in the eastern and central Pacific. Over the Hawaiian Islands 700-mb. mean heights (fig. 1), 1,000–700-mb. mean thicknesses, and sea level mean pressures were all above normal during March.

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CORRESPONDENCE

(*Continued from p. 106*)

We were not aware of a similar modulated technique in use by the Weather Bureau.

We are aware that saturation thresholds are somewhat difficult to work with, but for conditions of level plot land, we assume that a saturation point exists and that any precipitation in excess of this value is runoff and hence lost as far as crop use is concerned.

During the past year we have had the opportunity to compare atmometers with the Class A pan, and the buried 4-foot pan. These observations have not caused us to alter our point of view on the disadvantage of pans, generally. Frost is a serious limitation to the use of atmometers. (In this connection we have been experimenting with an instrument which withstands 7 degrees of frost.) Our co-workers in Canada have noticed time trends in Bellani plate atmometers only when air enters the cup or when the surface color or porosity changes because of dirt or accumulated salts.

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